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LIFE CYCLE MANAGEMENT

Strategy tool trial for office furniture

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Abstract
Purpose A strategic product development tool combining REACH and environmental and financial factors was previously developed for a coatings company. This paper presents results from refining this tool for an office furniture company, using life cycle assessment (LCA)-based environmental information, addressing the research questions: • Is it possible to combine information from REACH with the LCA approach to provide useful information for a furniture producer in their environmental product development process? • Does the approach developed for substances in mixtures need to be adapted for articles? • Is there a correlation between energy consumption and the environmental impacts analysed? • Will product designers get the same information independent of the environmental impact category used? – Will the strategy tool indicate the same ranking of products for all environmental impacts? – Does REACH information indicate the same set of priorities as those arising from LCA environmental data alone? (Do they agree, or is there a conflict?) • Will strategic decisions differ if different environmental indicators are in focus? The strategy tool's purpose is to analyse company product portfolios, identifying products that need redevelopment or redesign because of issues concerning hazardous substances, or environmental performance.
Methods The LCA data used is cradle-to-gate data from type III environmental declarations for 11 seating solutions. REACH Complexity, health hazard and environmental class indicators (based on risk phrases) are combined with financial data and LCA-based indicators. Correlations between energy consumption and environmental impact factors for these specific furniture products are investigated. Establishing any such correlations serves to simplify subsequent analysis in the product development process, by effectively reducing the number of indicators that need to be taken into consideration.
Results Correlations between energy consumption and the environmental impacts global warming, acidification, eutrophication and heavy metals are presented. Strategy tool figures are shown for energy consumption, ozone depletion potential and photochemical oxidation potential. The results for office chairs and conference/visitor chairs are presented separately, as the two types of chairs fulfil different functions.
Conclusions The correlation between energy consumption and certain environmental impact indicators affords a simplification of the product development process, since energy consumption can be used as a reasonable proxy for these indicators in this specific case. The results support acknowledged principles of Ecodesign. Energy and materials minimization improves environmental performance—higher recycled material content and proportion of renewable energy resources

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are also beneficial. Designers have to consider multiple aspects in parallel and the strategy tool is useful for this purpose; the furniture producer has gained useful product development insight. The tool is applicable for strategic choice of products for development or redesign that can be useful across many business sectors.

Keywords Environmental hazard · Furniture · Health hazard · REACH · Strategic decision making · Sustainable product development

1 Introduction

A strategy tool was developed for a coatings company as part of the Innochem project (innovations in response to new regulations of conventional materials in a life cycle, functional and holistic perspective) (Hanssen 2010). Innochem was conceived as a result of the challenges facing companies in Europe as a result of the adoption of the REACH directive (Registration, Evaluation, Authorisation and Restriction of Chemicals, Commission of the European Communities 2007). Innochem is a collaborative project involving companies (Jotun and HÅG) and research institutions (Ostfold Research, NIVA, University of Oslo and Aalborg University) financed by the Norwegian Research Council, the Confederation of Norwegian Enterprise and participating companies. Jotun is a coatings production company and HÅG is part of Scandinavian Business Seating, producing chairs for the office and conference environment. A coatings company produces products that are mixtures of substances, as defined in REACH. The work presented in this paper tested the application to articles of the strategy tool developed for substances in mixtures. An article is defined as "an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition" (Commission of the European Communities 2007). This was done in order to answer the following research questions:

- Is it possible to combine information from REACH with the life cycle assessment (LCA) approach to provide useful information for HÅG in their environmental product development process?
- How does the approach developed for a chemical mixtures producer need to be adapted for an article producer such as HÅG?

HÅG's interest in the strategy tool and their efforts to document the life cycle environmental impacts of their products are a consequence of their rigorous environmental policy (HÅG 2010), which requires that they produce chairs with a long life, that are made of durable and "environmentally friendly materials". Other activities in the Innochem project involving HÅG have focussed on using this LCA-based information for Ecodesign purposes. Thus, it was also of interest to answer the following research questions:

- Is there a correlation between energy consumption and the environmental impacts analysed?
- Will product designers get the same information independent of the environmental impact category used?
  - Will the strategy tool indicate the same ranking of products for all environmental impacts?
  - Does REACH information indicate the same set of priorities as those arising from LCA environmental data alone? (Do they agree, or is there a conflict?)
- Will strategic decisions differ if different environmental indicators are in focus?

2 Methods

The methodological basis for the strategy tool presented in this paper is in a similar form to the Eco-portfolio matrix presented by Brezet and van Hemel (1997), and the portfolio strategy matrix (Hedley in De Wit and Meyer 2004); both of which were inspired by the Boston Consulting Group's general Growth-Share Matrix (Kotler in Brezet and van Hemel 1997). In the Eco-portfolio matrix, the *y*-axis is a scale of potential environmental merit, while the *x*-axis represents market potential. The strategy tool presented in Askham et al. (2012) contains more complex environmental information, with each axis representing product qualities; the *y*-axis (volatile organic compound (VOC) concentration) is one indicator of environmental quality, while the *x*-axis represents an indicator incorporating three different REACH aspects. REACH complexity and health/environmental risk indicators are combined to make the index represented along the *x*-axis, called Total REACH, Health and Environmental Score. Table 1 gives a summary of the indicators used and how they were combined in the strategy tool for the coatings company and their offshore products range. Financial information (annual turnover for the specific products) has been incorporated in the size of the spheres presented in the figures presented in this paper. The strategy tool presents a more complex picture than the Eco-portfolio matrix, incorporating several environmental quality indicators into the tool.

The focus of this paper is to build on the original outline of the strategy tool (Askham et al. 2012) by presenting and discussing results from further testing of the tool in a different business sector (furniture). In addition, the environmental merit scale is also examined in further detail. Here, the data used for environmental merit is based on LCA results from existing environmental product declarations (EPDs) that the furniture-producing company has commissioned and published through the Norwegian EPD programme (EPD Norge 2011a). The

Table 1 Strategy tool matrix developed for coatings, used as the basis for the office furniture test (based on Askham et al. 2012)

Axis	Comment	Indicator	Definition
x-Axis: Total REACH, Health and Environmental Score	The sum of the indicators REACH complexity, health hazard class and environmental hazard class	REACH complexity	The number of exposure scenarios required for the product (Article 14, Commission of the European Communities 2007), scores assigned: 0 exposure scenarios=0; 1–2 exposure scenarios=1; 3–5 exposure scenarios=5; more than 5 exposure scenarios=10.
		Health hazard class Environmental class	Based upon the risk phrases (R-phrases) for effects on human health and the environment associated with chemicals in line with European hazard labelling directives (Council Directive 67/548/EEC, Directive 1999/45/EC). The R-phrases are grouped into three risk categories: low, medium and high. Table E.3-1 REACH CSA guidance (ECHA 2008) and COSHH (HSE 1999). The R-phrases hazard level classifications are weighted: low, medium and high hazard levels are assigned the values 1, 3 and 10, respectively (based on expert judgement at Jotun).
y-Axis: Environmental Merit	Specifically relevant for paints products	VOC concenetration	VOC concentration (grams per liter, g/l) in the product, shown in relation to a relevant VOC limit (Ökopol 2009).

LCA approach used for the EPD work can be described as retrospective (Tillmann 2000; Ekvall et al. 2005) or attributional (European Commission 2010a), and this is appropriate for type III environmental declarations and ecodesign projects (Baumann and Tillman 2004; European Commission 2010a). The methodological basis for calculation of the impacts included in the seating solution EPD is documented in Nereng and Modahl (2007; 2008) and Nereng (2009) and has been verified according to the Norwegian EPD system requirements. More details on the specific system boundaries and calculations on which each EPD is based can be found in the relevant EPDs from 2007 to 2009 (EPD Norge 2011b; EPD H03 320 2007; EPD H04 4400 2007; EPD H05 5300 2007; EPD Capisco 8106 2007; EPD H09 9230 2007; EPD H04 4470 2007; EPD H05 5370 2007; EPD Futu 2009; EPD Sideways 9732 2008; EPD Conventio Wing 9811 2008; EPD Conventio 9510 2007). The term energy consumption, as used throughout this paper, is the term used in the EPDs (The Norwegian EPD Foundation 2008). This is primary energy consumption for energy carriers consumed over the whole product life cycle, measured in megajoule units (in line with recommendations in European Commission 2010b); it does not include energy resources that are feedstocks for materials (for example crude oil as a feedstock for plastics production).

The emissions contributing to several of the environmental impact categories can be associated with fossil-based energy carrier consumption. There is also literature supporting the use of energy consumption as an indicator for the environmental performance of products (for example Huijbregts et al. 2006). If there is a strong correlation between energy consumption and other environmental impacts, it affords a potential simplification of the product development process, since energy consumption might then be used as a reasonable proxy for each of the indicators with which it correlates. In order to begin answering the research questions, correlations between the energy consumption data and a number of other environmental impact results from the EPDs were examined. Linear regression analysis was performed; using a linear least squares fit for the linear relationships shown in Fig. 1. This analysis was performed in Excel and the correlation coefficient (R^2) values are shown for the trend lines. This is in line with the approach used by Huijbregts et al. (2006) and Capello et al. (2009).

The environmental data from EPDs for 11 of HÅG's seating products was used to provide empirical data to test in the new business environment the strategy tool originally developed for mixtures of substances. The results from entering HÅG's product data into the strategy tool are presented in Fig. 2, 3, 4, 5, 6 and 7. These figures show how the strategy tool results differ with differing indicators of environmental quality (*y*-axis).

3 Results

3.1 Correlations between environmental indicators

The environmental impact results from the EPDs for the 11 seating solutions are presented in Table 2. It is often assumed that several environmental impacts are related to energy consumption. In order to answer the research question “Is there a correlation between energy consumption and the environmental impacts analysed?”, potential correlations between the different

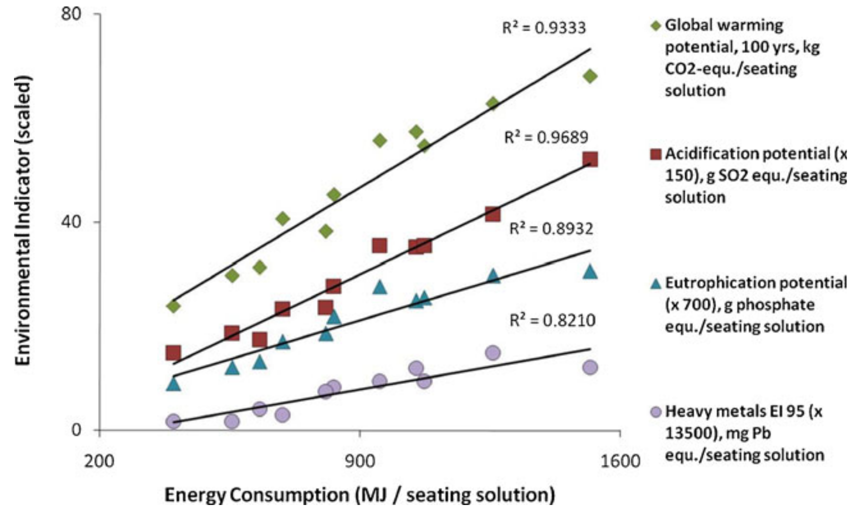


Fig. 1 Correlations between energy consumption and potential environmental impacts: GWP, EP, AP and heavy metals

environmental impact data were examined. Figure 1 shows the correlation of several potential impacts (global warming (GWP), eutrophication (EP), acidification (AP) and heavy metals) with the energy consumption data from the seating solution EPDs. The environmental indicator data in Table 1 shows that the different environmental impacts have different orders of magnitude. For the sole purpose of illustrating these impacts in a single figure, the data in Table 1 (other than GWP) were scaled, by applying a scaling factor to each data set as shown in the legend of Fig. 1. The correlations and R^2 values remain unchanged by this scaling. Figure 1 shows that these impacts have a strong correlation to energy consumption for these seating products. The data for the other impact categories (ozone depletion, ODP and photochemical ozone creation potential, POCP) did not correlate with energy consumption, or with each other.

The presence of the strong correlations between results for the environmental indicators energy consumption, GWP, EP, AP and heavy metals mean that the ranking of products will be similar for these indicators. The research question "Is there a correlation between energy consumption and the environmental impacts analysed?", is answered partly in the affirmative. For this case study, energy consumption correlates strongly with the indicators shown in Fig. 1 and weakly (or not at all) with the others—namely ODP and POCP. The next stage is to investigate the research questions regarding the ranking of products. Ranking is investigated by examining products' Total REACH, Health and Environment Scores in relation to the various environmental indicators. In the following analysis, the rank order is only shown for energy consumption and for the other indicators with which energy consumption does not correlate.

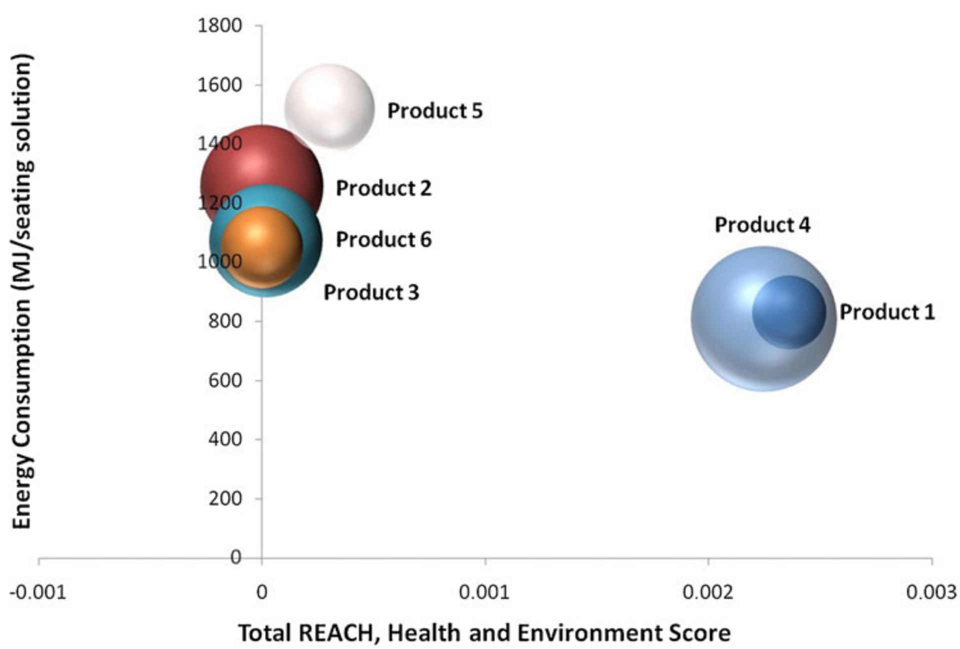
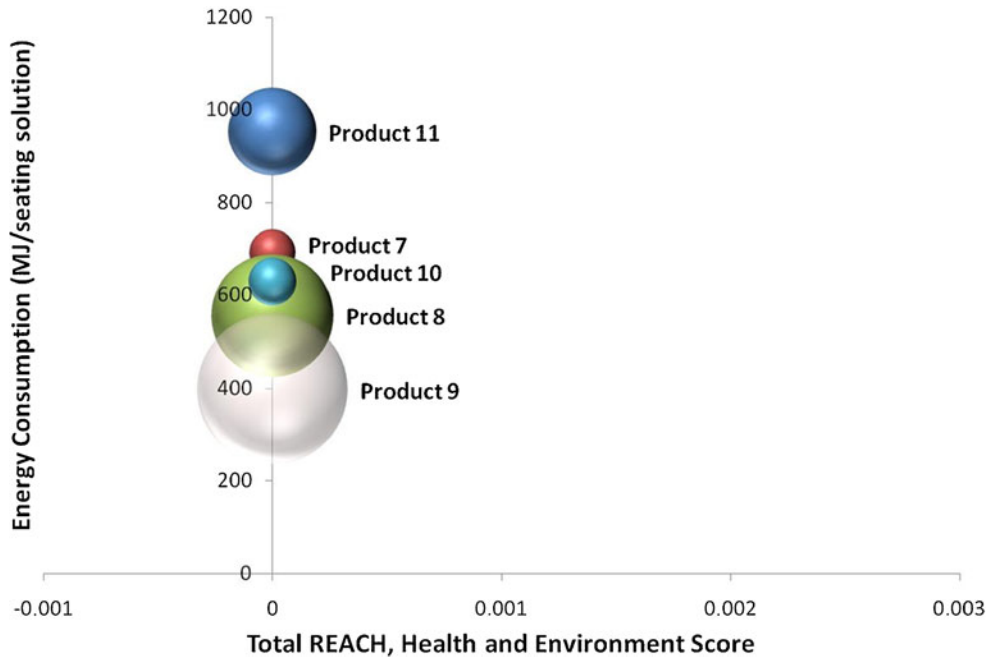


Fig. 2 Strategy tool results for office chair products; environmental quality scale—energy consumption

Fig. 3 Strategy tool results for visitor and conference products; environmental quality scale—energy consumption

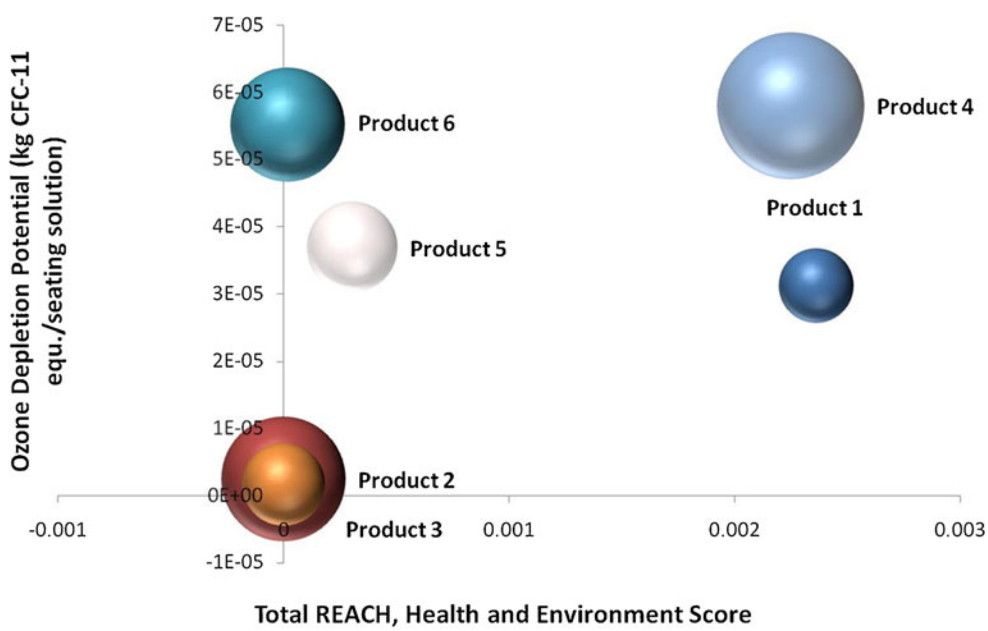


The rank order of products with respect to EP, AP and heavy metals is the same as that with respect to energy consumption—thus, in the specific context of this analysis, energy consumption may be used as a proxy for these other three indicators.

Figures 2, 3, 4, 5, 6 and 7 show results from the strategy tool for 11 seating solutions in HÅG's product range. Products 1–6 (Figs. 2, 4 and 6) are office chairs, and products 7–11 (Figs. 3, 5 and 7) are visitor or conference chairs. The size of the spheres shown in Figs. 2, 3, 4, 5, 6 and 7 represent the total sales volumes for these products in 2010 (Aaser 2010, personal communication). Figure 2 shows that the office chair with the largest sales volume (Product 4) has the smallest energy consumption. Products 1 and 4 have the smallest energy consumption and products 5 and 2 the largest.

Figure 2 shows that products 1, 4 and 5 all have a Total REACH, Health and Environment Score greater than zero. The reason for this is that these products contain a raw material (loctite) that has a hazard labelling requirement according to European hazard labelling directives (Council Directive 67/548/EEC of 27 June 1967; Directive 1999/45/EC). The amount of loctite used varies between the products, but is small in all cases. Furthermore, before the products reach the customer, the loctite glue has cured into an inert form, meaning that labelling of these products is not required.

Fig. 4 Strategy tool results for office chair products; environmental quality scale—ODP



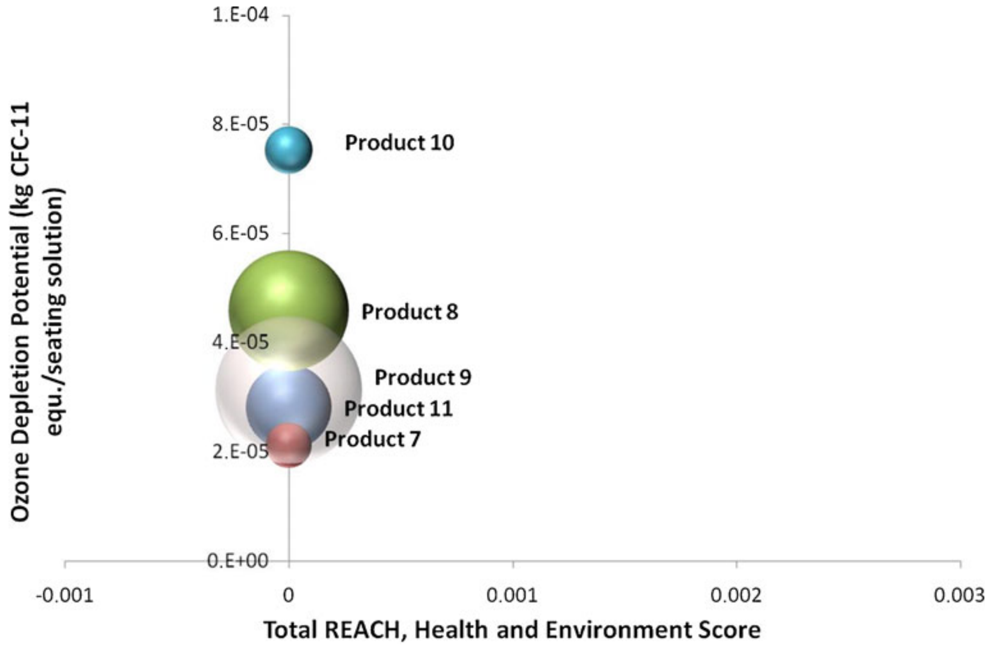


Fig. 5 Strategy tool results for visitor and conference products; environmental quality scale—ODP

When examining the LCA models on which the EPDs were based (Nereng and Modahl 2007; Nereng and Modahl 2008; Nereng 2009), it was found that energy consumption was largely attributable to the energy consumed in the value chains for metal components. Lower energy consumption is achieved for lightweight models with lower material consumption, also for models with higher recycled raw material content. Fossil energy carriers dominate energy consumption in the value chains for all of the chair models.

Figure 3 shows that the two visitor and conference products with the largest sales volumes are those with the smallest energy consumption. Product 11 has the largest energy consumption of the visitor and conference products. Figure 3 shows that none of these products contain components or substances that have a labelling requirement. Comparing Figs. 2 and 3, visitor and conference chairs have a lower energy consumption than office chairs. This is due to their lower material consumption.

Figures 4, 5, 6 and 7 show the Total REACH, Health and Environmental Score for the products as in Figs. 2 and 3, but with different environmental merit axes. Figures 4 and 5 show ODP, and Figs. 6 and 7 show POCP.

The office chair results in Fig. 4 show that Product 4 has the largest ODP and sales volume, and one of the largest Total

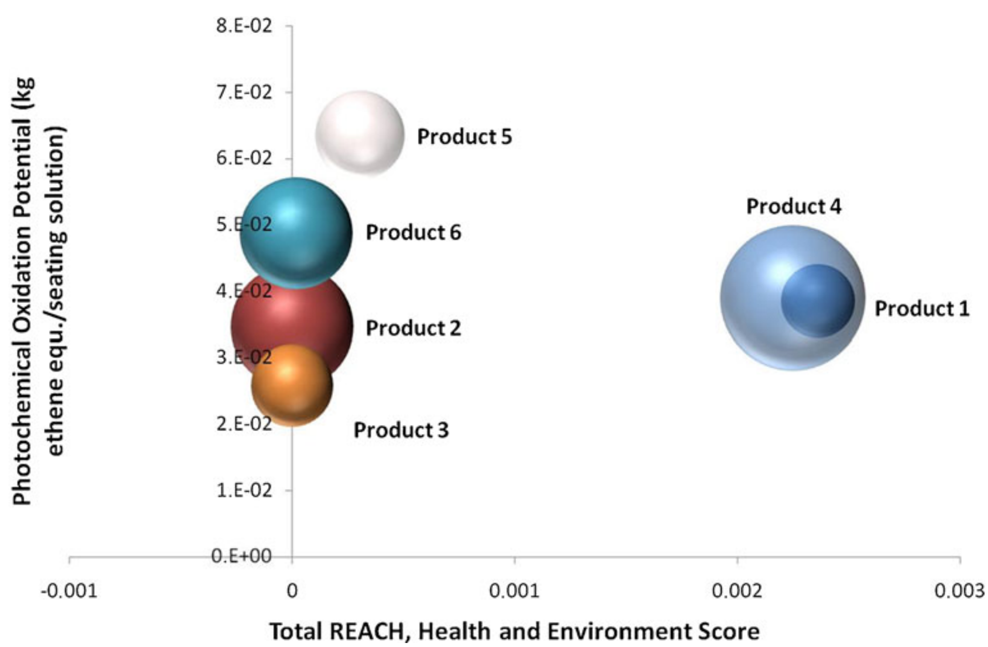


Fig. 6 Strategy tool results for office chair products; environmental quality scale—POCP

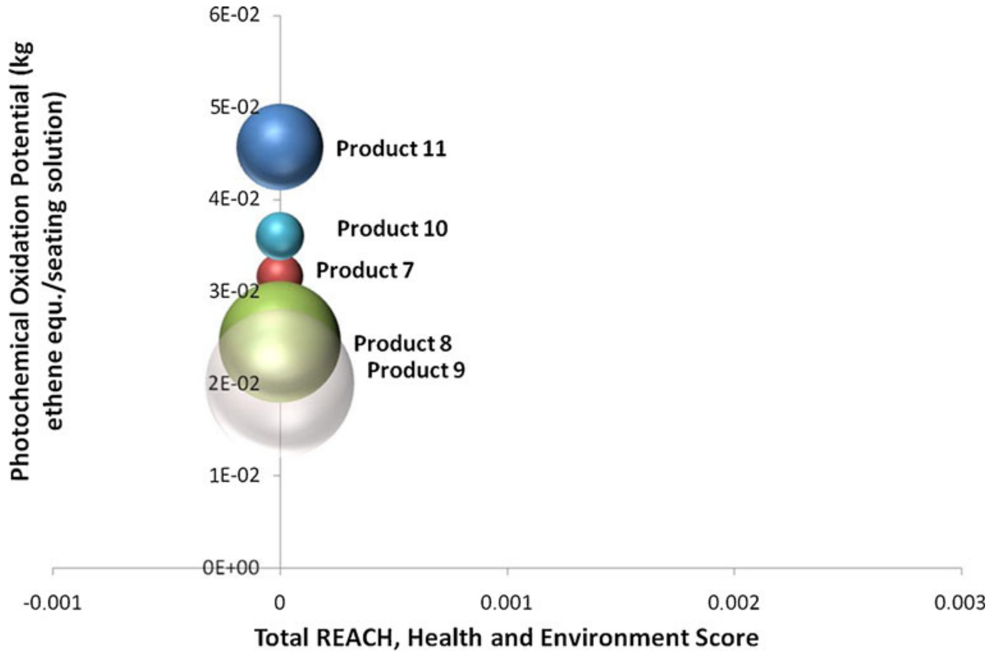


Fig. 7 Strategy tool results for visitor and conference products; environmental quality scale—POCP

REACH, Health and Environmental Scores. Products 4 and 6 are the office chairs with the largest ODP, and products 2 and 3 have the smallest. The visitor and conference chair results shown in Fig. 5 show that products 8 and 10 have the largest ODP, while products 7 and 11 have the smallest.

ODP largely arises from refrigerants and fire suppressants/flame retardants; the refrigerants are attributable to nuclear power in the electricity mixes used, and the flame suppressants used in the offshore and onshore oil and gas sector. Product 10 is a chair with a relatively high proportion of polypropylene plastic content, while product 7 contains aluminium with a high recycled content.

Figure 6 shows that products 5 and 6 are the office chairs with the largest POCP, whereas products 2 and 3 have the smallest. Figure 7 shows that products 10 and 11 are the conference/visitor chairs with the largest POCP, whereas 8 and 9 have the smallest. Emissions of non-methane volatile organic compounds (NMVOCs) are the main cause of POCP. Carbon monoxide and nitrous oxide emissions are also significant. Sulphur oxide emissions are only significant for two of the conference/visitor products (3 and 8), which have relatively high polyamide content; however, Figs. 6 and 7 show that these products perform relatively well overall in terms of POCP. NMVOC emissions arising from production of metals are mainly responsible for the POCP levels for the chairs with the worst POCP performance (both office and conference/visitor models, products 5 and 11).

Table 3 summarises the results for product ranking from the strategy tool according to the different environmental impact indicators for the environmental merit axis (y-axis) and Total REACH, Health and Environment Score (x-axis).

4 Discussion

The environmental impact results from the EPDs for the 11 seating solutions are presented in Table 2. It is a common assumption that several environmental impacts are related to energy consumption and several authors have identified cumulative energy demand as a useful indicator for the environmental performance of products (for example Capello et al. 2009; Huijbregts et al. 2006). In order to answer the research question "Is there a correlation between energy consumption and the environmental impacts analysed?", potential correlations between the different environmental impact data were tested. The potential impacts GWP, EP, AP and heavy metals show a strong correlation with the energy consumption data from the seating solution EPDs (with the specific energy systems used). The data for the other impact categories (ODP and POCP) did not show any significant correlation to energy consumption, or to each other. The summary of the product ranking results from the strategy tool test presented in Table 3 show that the choice of indicator for the environmental merit axis (y-axis) will be very significant for the results. This relates to the following research questions:

- Will product designers get the same information independent of the environmental impact category used?
  - Will the strategy tool indicate the same ranking of products for all environmental impacts?
  - Does REACH information indicate the same set of priorities as those arising from LCA environmental data alone? (Do they agree, or is there a conflict?)
- How will strategic decisions differ if different environmental indicators are in focus?

Table 2 EPD data for 11 HÅG seating solutions

Seating solution	Office/conference/ visitor	Energy consumption (MJ) Per seating solution	GWP (kg CO_2 equivalent)	AP (g SO_2 equivalent)	POCP (g ethane equivalent)	EP (g phosphate equivalent)	ODP, (mg CFC-11 equivalent)	Heavy metals EI 95 (mg Pb equivalent)
Product 1	Office	829	45	0.18	0.038	0.031	3.1 E−05	6.2 E−04
Product 2	Office	1257	63	0.28	0.035	0.043	2.4 E−06	1.1 E−03
Product 3	Office	1050	57	0.24	0.026	0.036	1.6 E−05	8.9 E−04
Product 4	Office	807	38	0.16	0.039	0.027	5.8 E−05	5.6 E−04
Product 5	Office	1518	68	0.35	0.064	0.044	3.7 E−05	9.0 E−04
Product 6	Office	1072	55	0.24	0.049	0.037	5.5 E−05	7.1 E−04
Product 7	Conference/visitor	691	41	0.16	0.032	0.025	2.1 E−05	2.3 E−04
Product 8	Conference/visitor	555	30	0.13	0.025	0.017	4.6 E−05	1.3 E−04
Product 9	Conference/visitor	397	24	0.10	0.020	0.013	3.1 E−05	1.3 E−04
Product 10	Conference/visitor	629	31	0.12	0.036	0.019	7.5 E−05	3.1 E−04
Product 11	Conference/visitor	952	56	0.24	0.046	0.040	2.8 E−06	7.1 E−04

The results shown in Fig. 1 and Table 3 show that it is not true that the strategy tool will indicate the same ranking of products for all environmental impacts.

The purpose of the strategy tool is to identify products that have the greatest need for further development, or redesign. Using the tool to analyse whether products in a product range have issues concerning hazardous substances and/or environmental performance that can become a problem in the future enables a company to target its product development resources efficiently. The results presented in this paper make it clear that HÅG's products do not generally have any significant REACH issues (Total REACH Complexity, Health and Environmental Score of zero, or very low in Fig. 2, 3, 4, 5, 6 and 7). This is an important result for HÅG, showing that they are unlikely to be significantly affected by REACH, a fact that can be used in communication with any customers that may be concerned about REACH compliance.

For producers of substances in mixtures, the Total REACH, Health and Environmental Score presented in Askham et al. (2012) was applicable to the mixture when threshold level values for component chemicals were exceeded. This was an example of data for "above threshold" situations typical for risk assessment (Potting et al. 1999). However, for HÅG's products, the amount of glue used was very small. It was nonetheless desirable to distinguish between the products that used small amounts of this raw material, from a "less is better" (Potting et al. 1999) standpoint. After in depth discussion in the project team, the tool was adapted to include the mass fraction of the labelled component in the required data. This enabled a more accurate calculation of the Total REACH, Health and Environment Score than if the quantitative mass fraction data were not included in the calculations. One result was that products 1, 4 and 5 were distinguishable by this score where otherwise they would not have been. This adaptation has been tested here and has also been adopted by the coatings company in further work. In considering the research question "does the approach developed for substances in mixtures need to be adapted for articles?", it is apparent that the strategy tool as presented in this paper has been useful in both business environments. Thus, the conclusion for this case study is that no significant adaptation is necessary.

The discussion process (leading to the mass fraction adaptation described above) yielded a proposal to include limit values for chemicals in order to differentiate between products. The limit values proposed were threshold limit values for classification of both human health and environmental hazards based on legal requirements for substance and product classification and labelling in Europe (Council Directive 67/548/EEC; Directive 1999/45/EC). The available product development information and REACH technical competence is often considerably different for an article producer than for a mixture producer. An article producer buying component parts, glues

Table 3 Product ranking from the strategy tool matrix indicators

Axis	Office chair products		Visit and conference products	
	The best	The worst	The best	The worst
Environmental merit scale (*y*-axis)				
Energy consumption	1 and 4	2 and 5	8 and 9	7 and 11
Ozone depletion potential	2 and 3	4 and 6	7 and 11	8 and 10
Photochemical oxidation potential	2 and 3	5 and 6	8 and 9	10 and 11
Total REACH, Health and Environment Score (*x*-axis)	2, 3 and 6	1 and 4	All the same	

and lubricants and obtaining safety data sheets (SDSs) for these (often multi-component parts, or mixtures of chemicals) will more readily fill out risk phrases that are in SDSs for the raw material, rather than enter specific chemical compositions from SDSs. Regarding the loctite glue component responsible for the hazard level shown, it is likely that article producers can readily determine the mass of a given raw material and its hazard rating from the SDS. In contrast, the limit values for hazard labelling, such as are used by producers of chemical mixtures, will not be readily available from SDSs. The specific loctite SDS available to HÅG during the strategy tool test (Reyher 2010) did not contain this threshold limit value information. Thus the mass ratio and risk level were combined, without relating them to the limit values for the relevant component chemicals in loctite. No general survey about whether or not this is a genuine difference in the needs for producers of substances in mixtures and article producers has been performed. However, this is could be explored further in future work.

There are some general trends for Ecodesign that arise from the LCA results (the environmental merit axes in Figs. 2, 3, 4, 5, 6 and 7). These indicate that low material consumption and low energy consumption is preferable. Models using a high proportion of recycled materials are also preferable. Lower consumption of fossil fuels for both energy and materials gives a lower score for all of the environmental indicators used. ODP results indicate that renewable energy sources are preferable. This is also supported by a recent European Environment Agency (EEA) report, which shows signs of the decoupling of economic activity with environmental impacts (although it should be noted that this report focuses mainly on greenhouse gas emissions, EEA 2011). This report finds that an increase in the use of renewable energy sources is a significant contributor to this decoupling, although decreased economic activity, as a result of economic recession is the most significant cause of European emissions reductions. All of these Ecodesign trends are in line with general Ecodesign principles that have been published by other authors (for example Brezet and van Hemel 1997).

HÅG has used the results of this strategy tool work as input into their company strategy and product development work. HÅG's focus on being at the forefront of Ecodesign based on LCA has resulted in the products that have the largest turnover also being those with the lowest energy consumption and GWP potential. Another interesting observation is that product 4 is a flagship product with high turnover. Thus, it is of interest to reduce all of the impact indicators to as close to zero as possible, this product will be prioritised for Ecodesign efforts in order to remove the Total REACH, Health and Environmental Score and reduce the other environmental impact indicators as far as possible. Product 1 is an old product in their range, which will not be prioritised for further development. The efficient identification of relevant products for further development or redesign is an example of how using the strategy tool has enabled important improvements to the company's product development process. This can thus lead to considerable improvements in the company's overall environmental performance.

HÅG's experience is that their customers are mostly interested in carbon footprint at the present time. In Figs. 2 and 3, the chairs with the largest sales volumes have the lowest energy consumption. This can indicate that HÅG's focus on reduction of their carbon footprint has had some success. HÅG has had focus on this issue in their product and supplier development work, and also in their marketing efforts. However, HÅG is also aware that there is increasing focus on other environmental aspects and have identified chemicals in products and chemical hazard as important for the future. As a consequence of this, HÅG has obtained the GREENGUARD certification (Greenguard 2011) for all of their products that have EPDs. Use of the strategy tool has enabled HÅG to identify three products in their range that contain a raw material with a labelling requirement, resulting in implications for the workplace environment at HÅG's production facility. From this work, HÅG has identified the relevant raw material and has challenged its product designers to seek alternative solutions. The loctite glue is used to secure screws firmly in place throughout the entire guaranteed product lifetime. Alternative designs of the relevant

parts are now being investigated, such as those involving mechanical solutions, namely washers that lock the screws into place.

Figures 2, 3, 4, 5, 6 and 7 illustrate the use of the Strategy tool to combine REACH Complexity, health hazard class, environmental class and environmental merit indicators in order to provide information about several aspects at once for company strategy and product design. This has in turn been used to identify one (small) area for redesign that applies to several products. This case study indicates an affirmative answer to the research question "Is it possible to combine information from REACH with the LCA approach to provide useful information for a furniture producer in their environmental product development process?".

One research question that has not yet been specifically addressed in this discussion is: "Does REACH information indicate the same set of priorities as those arising from LCA environmental data alone? (Do they agree, or is there a conflict?)" The visitor and conference products are not distinguishable by REACH Complexity, Health and Environmental Score (it is zero in all cases), thus there is no effective conflict in priorities for these products – priorities relate solely to LCA environmental indicators. Table 3 summarises the product rankings for the environmental indicators and the Total REACH, Health and Environment Score. Products 2, 3 and 6 come out best for the axis where REACH and chemical hazard information is in focus; these clearly differ from the best-ranked products with respect to energy consumption. In addition, product 6 is also ranked as one of the worst in terms of ODP and POCP. Thus, at least in some cases there is a marked conflict in priorities. This case study suggests that in general, product development should encompass both REACH information and LCA data, so as to adopt a balanced view on environmental performance factors. Trade-offs will often need to be considered; use of the strategy tool brings such trade-offs into clear focus and thus offers important information to the product developer.

The strategic product development decisions informed by the strategy tool concern which products are important for development and redesign efforts to improve the environmental performance of a product portfolio, as well as reduce REACH Complexity and health and environmental hazards associated with the product and its raw materials. The difference in ranking of products described above indicates that the answer to the final research question "Will strategic decisions differ if different environmental indicators are in focus?" is affirmative for this case study. Different products are likely to be focussed upon if different indicators are used as a basis for the decision. However, the strategy tool test for HÅG has also identified qualitatively different challenges for different products. HÅG has now a greater awareness of these different challenges and can combine this with other information (for example what their customers and stakeholders are concerned about) in order to make decisions about which products should be developed or redesigned. Such knowledge enables a proactive approach to stakeholder concerns.

5 Conclusions

The correlations between energy consumption and the potential environmental impact indicators GWP, AP, EP and heavy metals were sufficiently significant that energy consumption could be used as a reasonable indicator for all of these impacts. This conclusion is relevant for these seating products and their relevant energy systems. The strategy tool has been tested for 11 of HÅG's products and has resulted in important input into strategic and product development decisions. The following research questions have been answered affirmatively for the case study presented in this paper:

- Is it possible to combine information from REACH with the LCA approach to provide useful information for a furniture producer in their environmental product development process?
- Is there a correlation between energy consumption and the environmental impacts analysed?
- Will strategic decisions differ if different environmental indicators are in focus?

The work presented has also provided evidence (for this specific case) that the answers to the following research questions are negative:

- Will product designers get the same information independent of the environmental impact category used?
  - Will the strategy tool indicate the same ranking of products for all environmental impacts?
  - Does REACH information indicate the same set of priorities as those arising from LCA environmental data alone? (Do they agree, or is there a conflict?)
- Does the approach developed for substances in mixtures need to be adapted articles?

This testing of the strategy tool for articles, combined with the previous work presented in Askham et al. (2012) (using the tool for substances in mixtures), indicates that the tool can be useful both for substances in mixtures and articles. Thus, it is a tool for strategic choice of products for development or redesign that can be useful across many business sectors.

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